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LESSON PLANS AND THEMATIC EXPANSIONS ON SCIENCE ARTICLES

Mopping Up: Hierarchies and the Sloshing Bucket in the High School Classroom

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"Yo Mista, does evolution mean people will grow wings and fly around?" This is the question I am most frequently asked when introducing evolution to incoming ninth graders. The posing of this particular question tells me two things: (1) students have a very basic idea of what mutations and adaptations *are* but little understanding that mutations are slight and must be passed down through generations, which is a slow process when the affect is evolutionary change, (2) for evolution to occur, there often needs to be a catalyst (for example, drastic climatic change causing environmental degradation resulting in mass extinction opening niches). This hazy view of life is not surprising if we look at the way teachers teach. In 1956 Benjamin Bloom organized a hierarchy of intellect known as "Bloom's Taxonomy" (see Fig. 1).

As teachers, we often focus on the lowest level of intellect, that of knowledge or "recall". The term knowledge refers to the ability to regurgitate facts (names, dates, etc.) with little understanding of how and why those facts are meaningful. The purpose of the accompanying lesson plan is to focus on higher-level thinking skills regarding the process of evolution. Students should be able to analyze evidence, synthesize, and then evaluate its meaningfulness. The objective is not to teach *what* evolution is but for students to discover *how* evolution occurs and *why* it is so important.

Why Does Evolution Occur?

The first part of the lesson addresses why evolution occurs. I chose the evolution of Cetaceans (the order Cetacea), which includes whales, dolphins, and porpoises, from ungulates (hoofed land mammals) as an example for two reasons: (1) It is a common misconception that aquatic mammals evolved into terrestrial Mammalia, not the other way around, (2) it provides a very clear, linear example with interesting transitional species and an environmental causation that exemplifies the "sloshing bucket". As Dr. Eldredge states, "The greater the magnitude of the environmental event, the greater the change in ecosystems, including the magnitude of diversity loss through extinction; the greater the loss of higher taxa, the more different will be the newly evolved taxa, and thus the nature of the succeeding ecosystems that replaced the prior disturbed systems". It is difficult to imagine the connection between mesonychids[1] (an early wolf-like land mammal) and today's whales, (although Darwin alluded to the similarities between whales and bears in the first addition of *The Origin of Species*) but not so much when considering the environmental and "economic" influences of the Eocene epoch (55 mya, 10 my after the dinosaurs). The first essential question that needs to be asked is: Why would a terrestrial mammal return to the sea? The answer, in this case, is climatic. The Eocene epoch experienced a period of "global warming" (the Paleocene-Eocene Thermal Maximum or PETM) causing a sharp decline in the quality of food resources available to terrestrial mammals but creating warm seas teeming with fishes. This is very interesting because one would think warmer temperatures would increase the propagation of vegetation on land. It did but with a consequence. Fossil and sediment analysis reveals a large amount of carbon (both heavy and light) in both the oceans and air. The result was a massive die-off of about 40% of deep-ocean microorganisms that were literally "choked out".

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[1] There is some discussion as to the earliest ancestral link to order Cetacea.

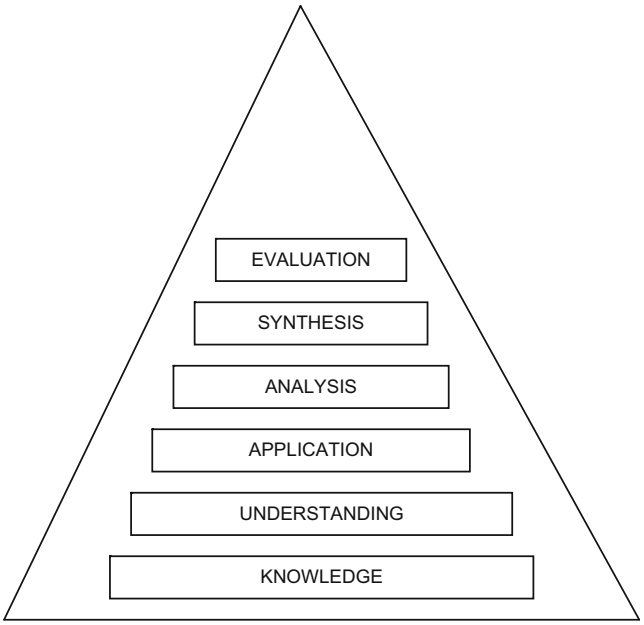


Fig. 1 Bloom's taxonomy

Plants, on the other hand, were eager to soak up the carbon in the air resulting in healthy but less nutritious plants. When plants ingest more carbon, their leaves produce less nutrition and also become harder to digest. Where the carbon came from (methane secreted from ice in the ocean floor or spewed into the air by volcanoes) is still in question. The result was that land mammals were already at an advantage, having developed complex digestive systems due to the coarse diets they were used to on land. This made the transition to aquatic feeding easier. They also filled a niche for an aquatic "avatar".

How does Evolution Occur?

Humans won't just sprout wings and fly around. If this were to happen, it would be a slow process over a long period of time with many transitional species in between. Most of all, there would need to be some climatic cause for this to happen. Sticking with the evolution of Cetaceans, some mutations/adaptations are obvious. Flukes and flippers, elongated snouts, the migration of nostrils to a blowhole are all fairly obvious. However, some adaptations are of equal importance yet not as recognizable. For example, the development of the inner ear allowing extremely acute hearing under water was one such adaptation. A more detailed account of the origin of Cetacea can be found in Douglas J. Futuyma's *Evolution* pp. 78–79 or in Stanley J. Rice's *The Encyclopedia of Evolution* pp.415–416. Another example is the birthing process (modern Cetaceans are born fluke first not head first or they would drown). The most important point that needs to be made is that evolution does not occur overnight and for no reason. Therefore this lesson will concentrate on transitional species from early land-dwelling mammals to modern dolphins and whales.

Lesson Plan Composition

The purpose of science is to gather empirical data to support or disprove a hypothesis. In the book *Evolutionary Science and Society: Educating a New Generation*, Robert Pennock uses the following example: "One tests a hypothesis as one tests a flashlight—by turning it on and seeing whether and how well it can illuminate one's surroundings". In keeping with this view, the lesson is centered around a discovery-based activity. This lesson plan was created using three resources: (1) the understanding by design (UBD) method of "Backwards Planning" (beginning with the learning objectives or end result of the lesson), (2) "The Workshop Model" format ("Do Now", mini-lesson, activity, share, reflection), and (3) the National Education Support Service (NESS) Teaching Standards for evolution. Each of these will be explained more thoroughly in the lesson plan itself.

Class: 9th grade Biology (with the possibility of modification and extension)

Aim: (Objective of the lesson)

- How and why does evolution occur?

Enduring Understanding: (What students will remember after the lesson is over)

- Evolution consists of gradual changes passed on through many generations through natural selection acting on variation. The source of that variation is mutation.
- Evolution happens for a reason; for example, dramatic climatic change causing environmental degradation can result in mass extinction which in turn creates ecological opportunities that may trigger evolutionary change.

- The greater the catalyst, the more rapid the evolutionary process (rapid change in order Cetacea within 20 my with little change in the last 35 my).
- An adaptation can not be acquired within the lifetime of an individual organism.

Essential Questions (unanswerable except by opinion/ guided higher-order thinking questions)

- What new taxa would arise if the world suddenly warmed?
- What new taxa would arise if the world suddenly cooled?
- Can life exist without vegetation?

NESS Teaching Standards Met:

- Unifying concepts and processes in Science
  - Systems, order, and organization
  - Evidence, models, and explanations
  - Change, constancy, and measurement
  - Evolution and equilibrium
  - Form and function
- Standard A: Science as Inquiry
  - Abilities necessary to do scientific inquiry
  - Understandings about scientific inquiry
- Standard B: Physical Science
  - Structure and properties of matter
  - Interaction of matter and energy
- Standard C: Life Science
  - Biological evolution
  - Interdependence of organisms
  - Behavior of organisms

Do Now: (A question or activity students can begin immediately on their own upon the start of class)

- Compare and contrast native Swiss and the Quichua people of the Amazon Rainforest.
- Purpose: To show that the environment influences physical appearance. Skin color (caused by melanin needed to protect against ultra-violet rays in equatorial areas receiving direct sunlight but also blocking vitamin D from being absorbed), hair color and type, and eye color are all physical differences caused by environmental influences.
- Note: Can also fuel interesting discussion on the falsity of Social Darwinism and interesting sociological and cultural comparisons.

Mini-Lesson: (A short introduction providing background knowledge necessary to complete the activity portion of the lesson)

- Use the "Do Now" as a springboard into the diversity of taxa due to environmental influences.

Activity: (Students perform some sort of exploratory activity designed to illustrate a concept)

- See reproducibles 1–5 (in Appendix).
- Students begin with a line drawing of an ungulate on a coordinate plane.
- Students replace specific coordinate points creating a new transitional species.
- Students document the evolutionary changes and justify why each takes place.
- Students begin with an ungulate (mesonychia) and end with Balena, moving through each known transitional species showing the process of Cetacean evolution.
- *Note:* Drawings are *not* done to scale.

Share: (An opportunity for students to express in their own words what they are observing)

- Students will share the changes they observed in each transitional species and explain why each is important/ useful.

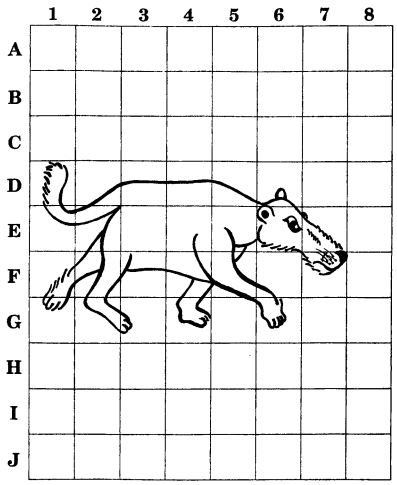
Reflection: (An opportunity for students to reflect on what they have learned and apply it in a different manner)

- What adaptations are taking place that are not externally visible?
- This allows the opportunity to discuss unseen adaptations (inner ear, etc.).

Resources:

- *Understanding by Design* by Jay McTighe and Grant Wiggins
- *Encyclopedia of Evolution* by Stanley A. Rice
- *Evolution* by Douglas J. Futuyma
- *Evolutionary Science and Society: Educating a New Generation* Edited by Joel Cracraft and Rodger W. Bybee
- *Guns, Germs and Steel* by Jared Diamond

Appendix



1. MESONYCHID

2. AMBULOCETUS

D1, D6, D7, E6, E7, F1, F7, G1, G2, G4, G6

3. RODOECETUS

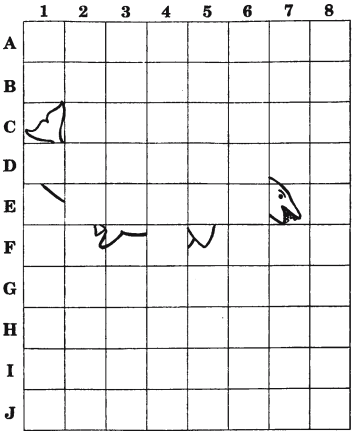
C1, D1, D6, D7, E1, E2, E5, E6, E7, F1–F7, G1–G7

4. BASILOSAURUS

C1, D7, E1, E7, F2, F3, F5, F7

5. ORDONTOCETES

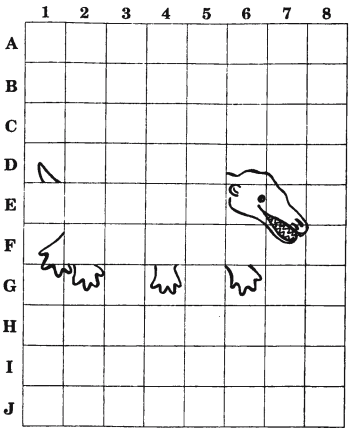
C1, C4, D1, D4, E1, E7, F3, F5, F6, F7



4. BASILOSAURUS

WHAT CHANGES DO YOU OBSERVE?

WHY ARE THESE CHANGES HELPFUL?



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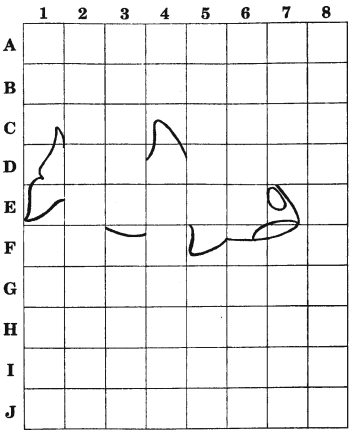

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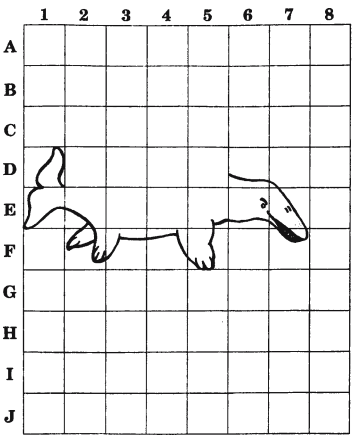

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